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ON THE RELATIONSHIP OF GOLD MINERALIZATION AND ULTRAMAFIC VOLCANIC ROCKS IN THE TIMMINS AREA

by

D. R. Pyke

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ABSTRACT

Many of the gold deposits in the Timmins area show a close spatial association to ultramafic metavolcanics. Available analytical data suggests that ultramafic rocks, in particular primative Archean ultramafic volcanic rocks, contain significantly higher gold contents than other major rock types. It is proposed that the ultramafic volcanic rocks formed the principal source bed for the gold deposits in Timmins; the gold was concentrated in dilatant zones through a process of lateral secretion when the area was subjected to dynamothermal metamorphism. Delineation of hitherto unrecognized ultramafic volcanic rocks could be an important guide to the discovery of further gold deposits.

ON THE RELATIONSHIP OF GOLD MINERALIZATION AND ULTRAMAFIC VOLCANIC ROCKS IN THE TIMMINS AREA, NORTHEASTERN ONTARIO

by

D.R. Pyke[1]

Introduction

Gold mineralization was first discovered in the Timmins area in 1909, and since that time the nearly 30 mines in the area have had a total production of approximately 50 million ounces. A number of sources have been postulated for the mineralization; most theories (Carter 1948; Ferguson et al. 1968; Griffis 1968) have inferred derivation of the gold from small stocks of quartz-feldspar porphyry, generally considered to be of subvolcanic origin (Griffis 1968; Hurst 1936). Other less popular theories have postulated lateral secretion of the vein material from the nearby volcanic rocks (Hurst 1935), or derivation from the large granitic batholiths (George 1967; Jones 1948) generally considered to be of Kenoran age.

The purpose of the present paper is to show that the ultramafic volcanic rocks in the Timmins area may have provided the main "source bed" for the gold mineralization, with the gold subsequently being mobilized, possibly in a large part during carbonatization of the ultramafic rocks, and deposited in structurally favourable sites. The evidence for this is threefold: (1) the close spatial association that exists between the ultramafic volcanic rocks and the gold deposits, (2) analytical data on the gold content of ultramafic volcanic rocks, and (3) comparison with other Archean gold-bearing camps.

The source bed concept, whereby the mineralization is derived from the enclosing supracrustal rocks is not new (Sullivan 1948), and has been credibly demonstrated by Boyle (1961) for the gold deposits in the Yellowknife area. Here, Boyle showed that the presence of gold-bearing veins can be adequately explained by means of lateral secretion from the surrounding volcanic and sedimentary rocks during dynamothermal metamorphism.

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[1]Chief, Southern Archean Subsection, Precambrian Geology Section, Geological Branch, Ontario Division of Mines. Manuscript approved for publication by the Chief Geologist, 28 April 1975.

Limited published data by Shcherbakov and Perezhogin (1964) indicates that ultramafic rocks contain relatively high concentrations of gold in comparison to other rock types. The above authors have shown that there is a decrease in the gold content from ultramafic and mafic rocks to felsic rocks, by a factor of about 2 to 3. The average gold content of ultramafic rocks and "intrusive basalts" is 0.0094 ppm and 0.010 ppm respectively, whereas granites and granodiorites average 0.0032 ppm and 0.0040 ppm respectively. Shcherbakov and Perezhogin attribute the high gold content of ultramafic rocks to the concept of electronegativity, which they say provides a quantitative expression for the relative importance of ionic and covalent bonding in silicates. Gold, which has a very high electronegativity, tends to be bound with compounds having a minimum amount of ionic bonding, as found in the neso- and inosilicates (olivines and pyroxenes), thereby accounting for the high gold content of ultramafic rocks. Tectosilicates (feldspars and quartz) on the other hand have a maximum amount of ionic bonding. Shcherbakov and Perezhogin also state that the extrusive variety of rocks tend to contain more gold than their intrusive equivalents.

Viljoen et al. (1969) recognized the importance of the high gold content of the ultramafic rocks in the Barberton area of South Africa. Here, they considered that the komatiitic rocks[1] were the principal transporters of gold from the mantle for the deposits found within the Steynsdorp goldfields.

General Geology of the Timmins Area

With the exception of a few diabase dikes and minor Middle Precambrian sedimentary rocks, all the bedrock in the area is of Early Precambrian (Archean) age (Figure 1). The Early Precambrian metavolcanics comprise two groups (Figure 2): The Deloro Group, and the Tisdale Group. This terminology follows that adopted by Dunbar (1948), and subsequently used by other workers (e.g. Carlson 1967; Hogg 1950; Leahy 1971). Although the Deloro Group was interpreted to be the older of the two (Dunbar 1948), it was never firmly established, as the two groups were separated structurally by the Destor-Porcupine Fault.

Of major significance in the present correlation of the volcanic stratigraphy in the Timmins area is the recognition of ultramafic flows north and south of the Destor-Porcupine Fault. If, the ultramafic flows on opposite sides of the fault are correlative, as seems reasonable, then the original interpretation that the Deloro Group is older than the Tisdale Group is confirmed.

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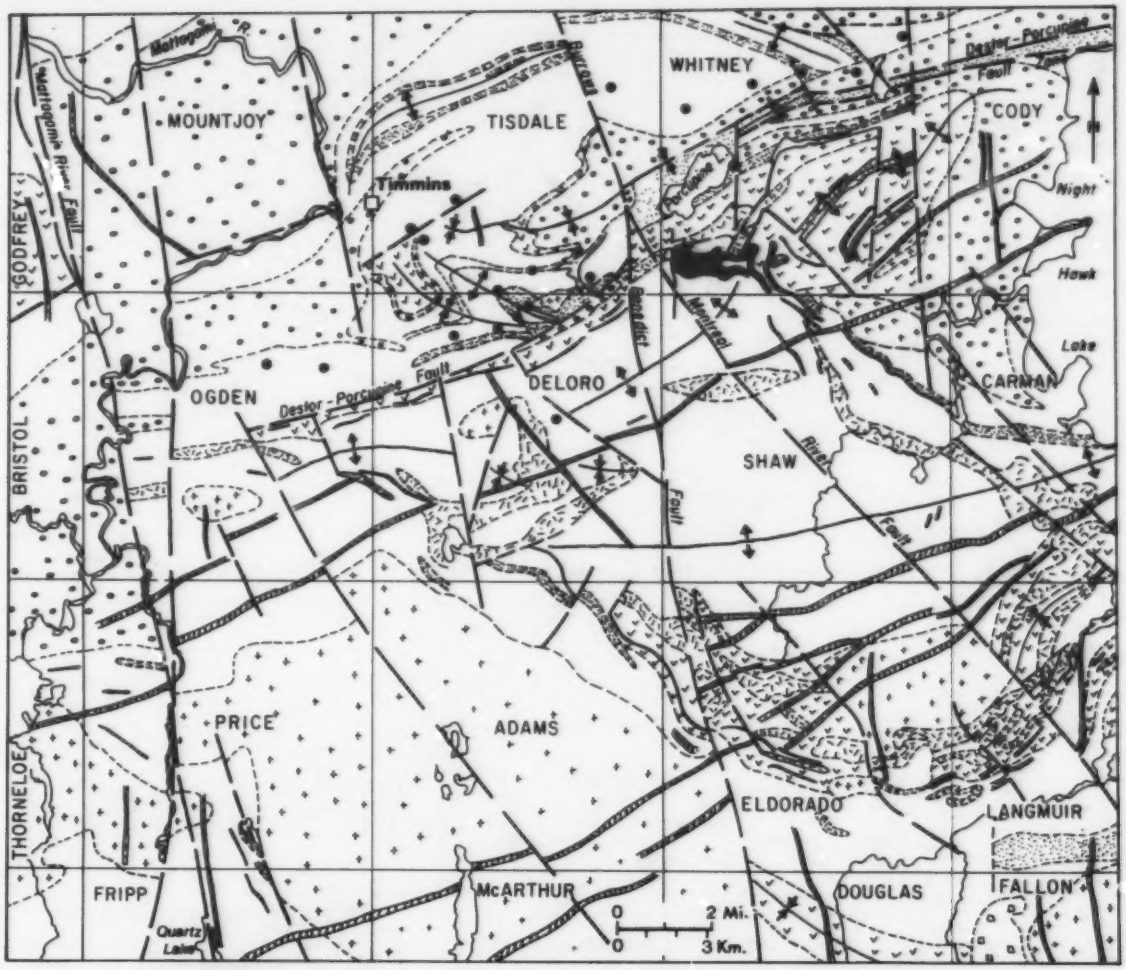
[1]The term komatiite
- Includes a distinct suite of ultramafic volcanics and magnesium basaltic rocks characterized by high CaO/Al_2O_3 ratios (Viljoen and Viljoen 1969).



LEGEND

MIDDLE PRECAMBRIAN

Cobalt Formation

Greywacke, arkose, argillite, conglomerate

Unconformity

EARLY PRECAMBRIAN

Diabase*

Intrusive Contact

Granitic intrusive rocks

Intrusive Contact

Ultramafic intrusive rocks

Intrusive Contact

Sediments (dominantly turbidites)

Iron formation

Felsic to intermediate volcanics

Mafic volcanics

Ultramafic volcanics

*Some diabase dikes are Middle to Late Precambrian

SYMBOLS

Location of gold mine (present and past producer)

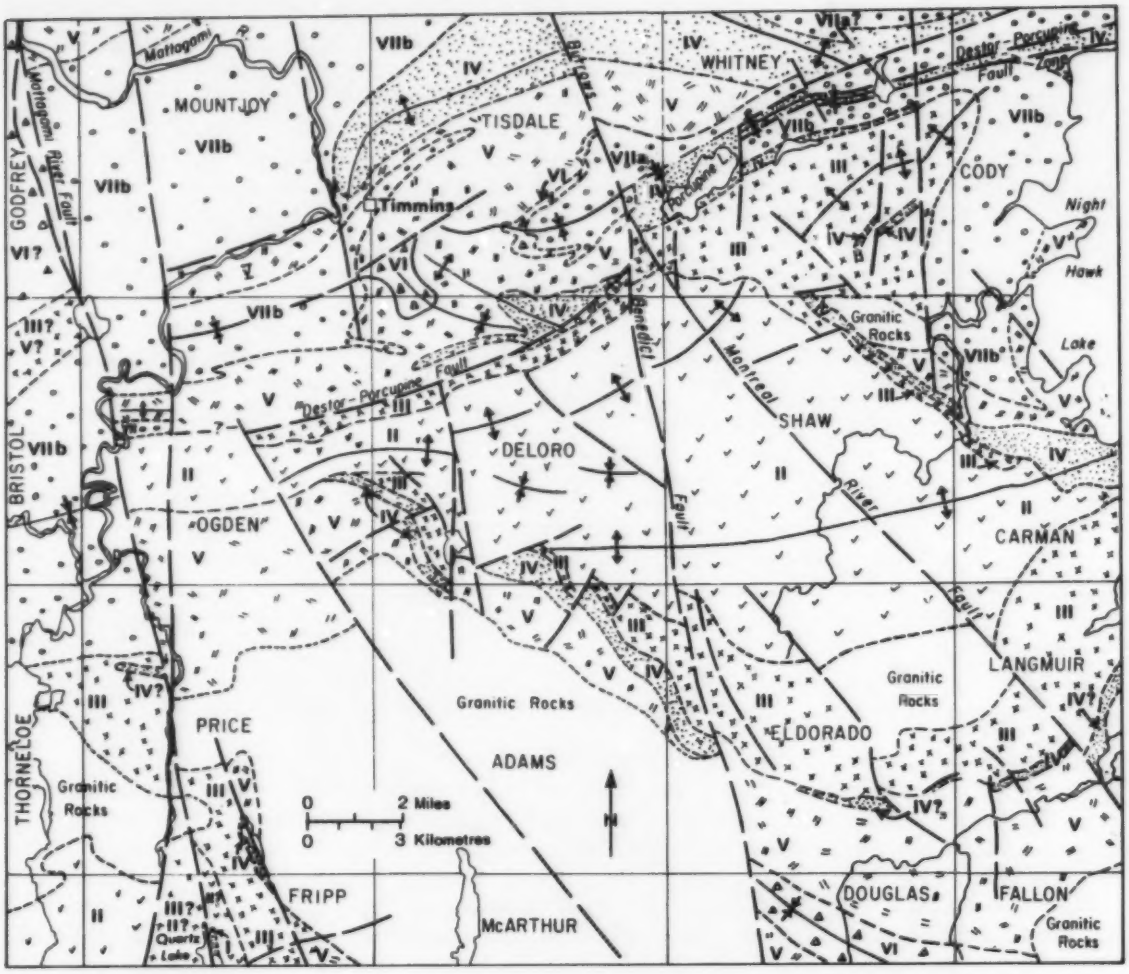
Fault

Anticlinal axis

Synclinal axis

Geological boundary

Figure 1. Geological sketch map of the Timmins area (after Pyke 1974a).



LEGEND

Porcupine Group

VII a Upper Formations

VII b Lower Formations

Tisdale Group

VI Krist Formation

V Schumacher Formation

IV Goose Lake Formation

Deloro Group

III Boomerang Formation

II Redstone Formation

I Donut Lake Formation

SYMBOLS

Geological boundary

Fault

Anticlinal axis

Synclinal axis

Figure 2. Tentative distribution of stratigraphic units in the Timmins area (after Pyke 1974a).

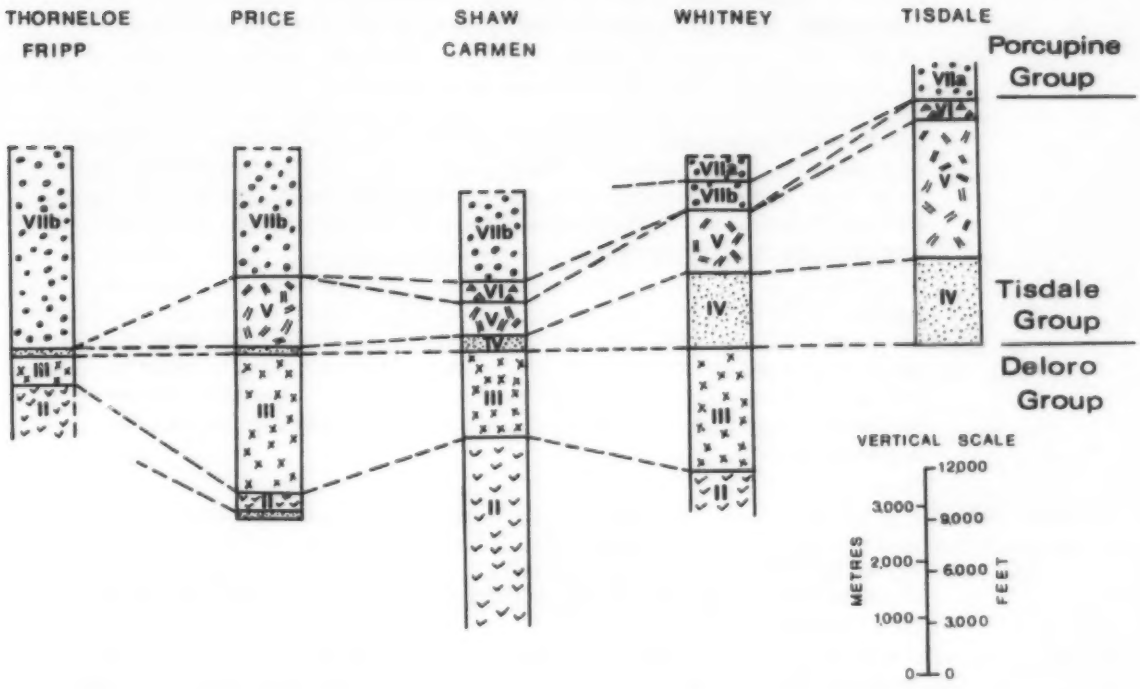


Figure 3. Stratigraphic columns for the Timmins area illustrating generalized correlations for the various stratigraphic units (numerals refer to same formations as in Figure 2)

Table 1 DESCRIPTIVE TABLE OF FORMATIONS FOR THE TIMMINS AREA

Deloro Group

I Donut Lake formation
Ultramafic metavolcanics - a poor exposure of talcose ultramafic rock near Quartz Lake in the southeast part of the area probably represents the continuation of the ultramafic metavolcanics outlined in Fripp Township (Pyke 1973), which form part of the lower volcanic cycle in the Peterlong Lake area.

II Redstone formation
Mafic metavolcanics, consists mainly of calc-alkaline andesite and basalt, with lesser tholeiitic basalt; best exposed in northern Shaw Township and the north and east parts Deloro Township. Pillow breccia and intercalated tuff and lapilli-tuff are common.

III Boomerang formation
Intermediate to felsic metavolcanics, composed largely of tuff and lesser tuff-breccia. Interlayered sulphide- and oxide-bearing iron formation is common, and locally serves to outline the sequence in lieu of intermediate to felsic metavolcanics.

Tisdale Group

IV Goose Lake formation
Ultramafic metavolcanics, and high magnesium (greater than 10 percent MgO) basalts.

V Schumacher formation
High iron (greater than 12 percent FeO_{total}) tholeiitic basalts appear to dominate: commonly pillowed, locally variolitic, and best developed in Tisdale Township. Interlayered ultramafic metavolcanics are locally common, as in southern Langmuir Township.

VI Krist formation
Felsic metavolcanics, largely composed of breccia and tuff-breccia.

Upper Metasedimentary Group (Porcupine Group)

VII Metasediments consisting dominantly of interlayered greywacke, siltstone, and lesser conglomerate form part of a turbidite sequence, the lower portion of which is time equivalent to the Tisdale Group and the upper portion of the Deloro Group (Figure 3). This turbidite sequence, together with a thin sequence of overlying fluvitile sedimentary rocks, has recently been classified as the Porcupine Group (Lorsong 1975).

Previously (Pyke 1974a) the volcanic stratigraphy was divided into six formations numbered I to VI. This numbering system is retained but in addition formational names are introduced. A detailed description of the formations is currently in preparation and is not presented here.

Table 1 is a brief outline of the apparent stratigraphic succession from oldest to youngest in the Timmins area. Representative chemical analyses of the various volcanic rock types are given in Table 2.

Large, generally sill-like bodies of medium- to coarse-grained dunite and peridotite were emplaced almost entirely within the Deloro Group of mafic and felsic to intermediate metavolcanics. Conceivably, some of the sills may have acted as magma reservoirs, thereby providing a source for some of the overlying ultramafic metavolcanics of the Tisdale Group. Differentiation has produced a narrow zone of pyroxenite and gabbro along the roof of some of the sills.

Minor, small epizonal quartz-feldspar porphyry intrusions, probably of sub-volcanic derivation, are intrusive into the metavolcanics. A small stock of biotite-hornblende trondhjemite outcrops in east-central Eldorado Township, a large stock of porphyritic granodiorite underlies much of Adams and Price Townships, and a small stock of monzonite outcrops into the southeast corner of the area. The eastern margin of a large complex batholith (Pyke et al. 1973) extends into the southwest part of the area.

Northeast-trending diabase dikes of Middle and Late Precambrian age (Pyke et al. 1973) traverse the area. Many of the north-trending diabase dikes are probably of Early Precambrian age, although it is recognized that some may be Middle to Late Precambrian in age.

Minor Middle Precambrian sedimentary rocks of the Cobalt Group occur in the southeastern part of the area.

A major structural break, the Destor-Porcupine Fault trends northeast across the northern part of the area (Burrows 1924; Hurst 1939; Ferguson et al. 1968).

North of the fault two periods of folding can be discerned (Figure 4); an original north-trending series of folds which were subsequently refolded about an east-northeast axis. Interpretation of the overall fold pattern, however, is particularly hampered where there was extensive faulting, as in north Whitney Township. Nevertheless, the refolded pattern indicates a doubly plunging syncline, the axis of which is delineated by the Porcupine Syncline (Ferguson et al. 1968), which in the northeastern part of the area is coincident with the Destor-Porcupine Fault.

TABLE 2 Chemical Analyses of Volcanic Rocks from the Timmins Area

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	49.4	44.8	50.9	43.0	51.4	46.7	51.8	53.4	51.7	62.0	64.0	56.9	68.4	64.0
Al_2O_3	5.46	6.01	6.44	7.84	7.12	8.57	13.1	13.6	14.3	16.1	14.5	16.8	13.2	19.6
Fe_2O_3	1.50	2.3	.48	3.3	2.2	.95	3.7	3.2	2.5	1.77	1.96	2.17	.35	.01
FeO	8.78	8.78	11.31	14.02	9.09	11.6	9.54	10.62	8.31	4.09	4.44	5.07	2.07	3.16
MgO	21.9	29.7	18.9	27.1	15.8	20.0	3.70	6.53	8.35	4.66	3.11	6.57	3.39	1.40
CaO	11.9	6.88	10.72	2.78	12.4	10.59	13.0	7.42	9.72	6.98	7.10	8.01	5.00	4.98
Na_2O	.25	.27	.28	.33	.44	.40	2.77	3.03	2.96	3.14	3.63	2.71	5.19	4.35
K_2O		.11	.03	.13	.67	.05	.19	.29	1.13	.35	.20	.66	1.24	1.68
TiO_2	.55	.74	.65	1.31	.57	.79	2.03	1.63	.87	.66	.72	.71	.55	.55
P_2O_5	.02		.01			.03				.12	.21	.18	.09	.14
S	.11	.17	.04			.02							.01	.06
MnO	.21	.21	.23	.26	.30	.27	.24	.19	.22	.12	.14	.16	.79	.05

1. P-672-74 - Ultramafic flow-high Mg basalt, Donut Lake Formation
2. T-25-73 - Ultramafic flow, Donut Lake Formation
3. P-298-74 - Carbonatized ultramafic flow-high Mg basalt, Donut Lake Formation
4. T-544-73 - Carbonatized ultramafic flow, Goose Lake Formation
5. P-653-74 - High Mg basalt, Goose Lake Formation
6. P-657-74 - High Mg basalt, Goose Lake Formation
7. P-602-74 - High Fe tholeiitic basalt, Schumacher Formation
8. P-660-74 - High Fe tholeiitic basalt, Schumacher Formation
9. P-651-74 - Tholeiitic basalt, Schumacher Formation
10. P-222-73 - Calc-alkaline andesite, Redstone Formation
11. P-104-73 - Calc-alkaline andesite, Redstone Formation
12 P-269-73 - Calc-alkaline basalt, Redstone Formation
13. P-414-69 - Calc-alkaline decite-andesite, Boomerang Formation
14. P-692-74 - Calc-alkaline rhyolite-dacite, Krist Formation

South of the Destor-Porcupine Fault the Shaw Dome forms the main structural feature, the axis of which trends about east-west across the southern part of Shaw Township. It appears that this domal structure is the result of the same superimposed folding to which the rocks north of the Destor-Porcupine Fault were subjected.

The Early Precambrian volcanic and sedimentary rocks have undergone regional metamorphism to the lower and middle greenschist facies.

Ferguson et al. (1968) have given a comprehensive description of the gold-bearing veins and mines of Tisdale Township, and Carlson (1967) has described the mines and showings in Ogden, Deloro and Shaw Townships. Virtually all the production from the area has been from quartz-carbonate veins in the metavolcanics and metasediments north of the Destor-Porcupine Fault. Most of the auriferous quartz veins tend to be along anticlinal axes, and many are in proximity to stocks of quartz-feldspar porphyry (Ferguson et al. 1968).

Geology of the Timmins Gold Camp

Of special significance in establishing a correlation between the ultramafic metavolcanics and the gold deposits in the Timmins area is synthesising of the structural and stratigraphic relationships of this gold mining area, which the maps of Hurst (1939), Ferguson et al. (1968) and Ferguson (1958a, 1958b) provide an excellent base. The following discussion is concerned mainly with Tisdale Township and the northern extremity of Deloro Township; that is the area west of the Burrows-Benedict Fault and north of the Destor-Porcupine Fault. This area accounts for the bulk of the gold production from the Timmins area.

The eastward-plunging Porcupine Syncline forms the dominant fold structure in the above area (Figures 1 and 4). A strong penetrative ENE-trending lineation that plunges 45 to 60 degrees accompanies this folding. To the north and south of the eastward-plunging Porcupine Syncline the metavolcanics are folded into two main anticlinal structures (Figure 4) which plunge westerly to near vertical; that is opposite to the plunge of the Porcupine Syncline. The reversal of plunge and correspondingly the facings of the metavolcanics can be adequately explained by refolding, whereby an original north-trending series of folds was subsequently refolded about an east-west axis; this is shown diagrammatically in Figure 5.

Although numerous lineation, bedding and cleavage plane measurements were made, no conclusive evidence for two periods of folding is present in the metasediments of the upper part of the Porcupine Group. Furthermore, very few small scale fold structures occur in these metasediments; those present

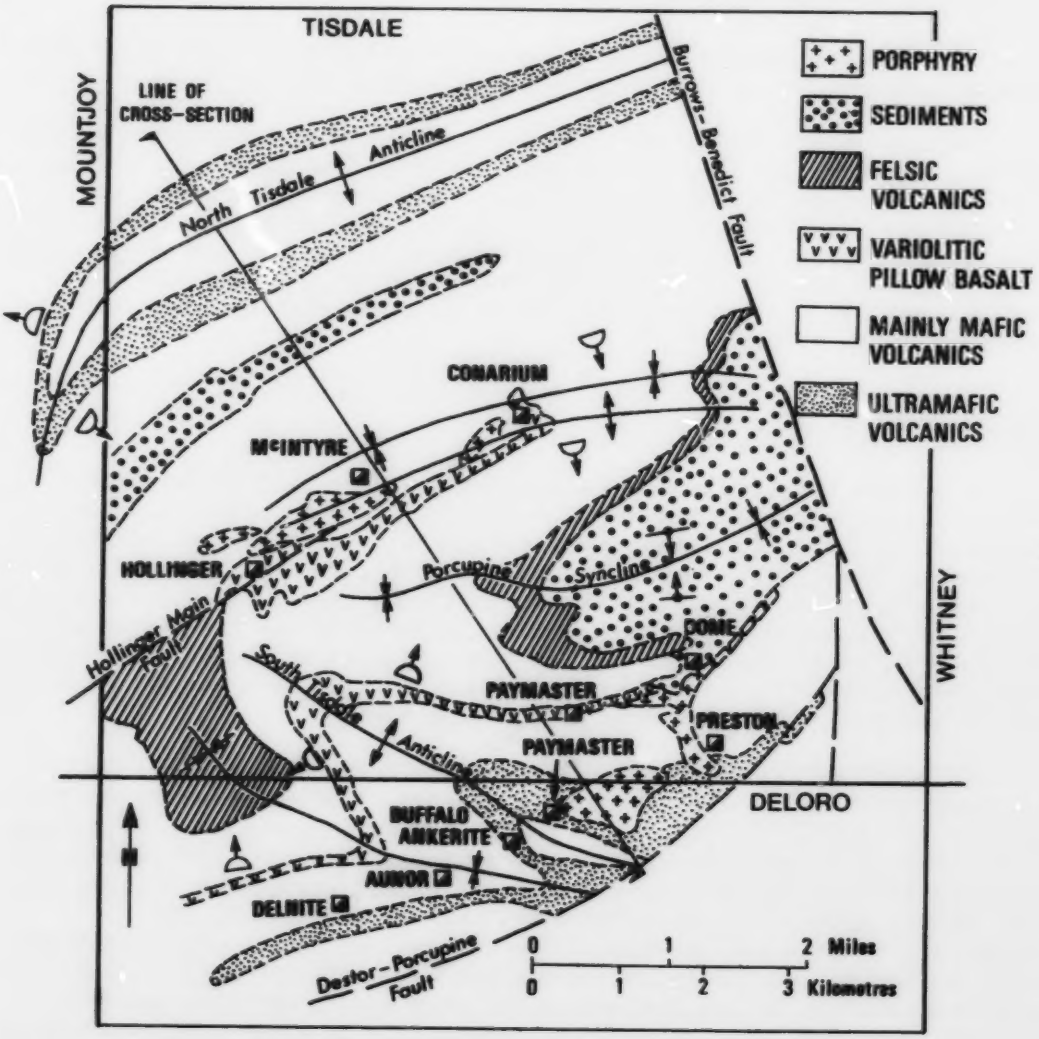


Figure 4. General geology of Timmins gold camp (after Hurst 1939 and Ferguson et al. 1968).

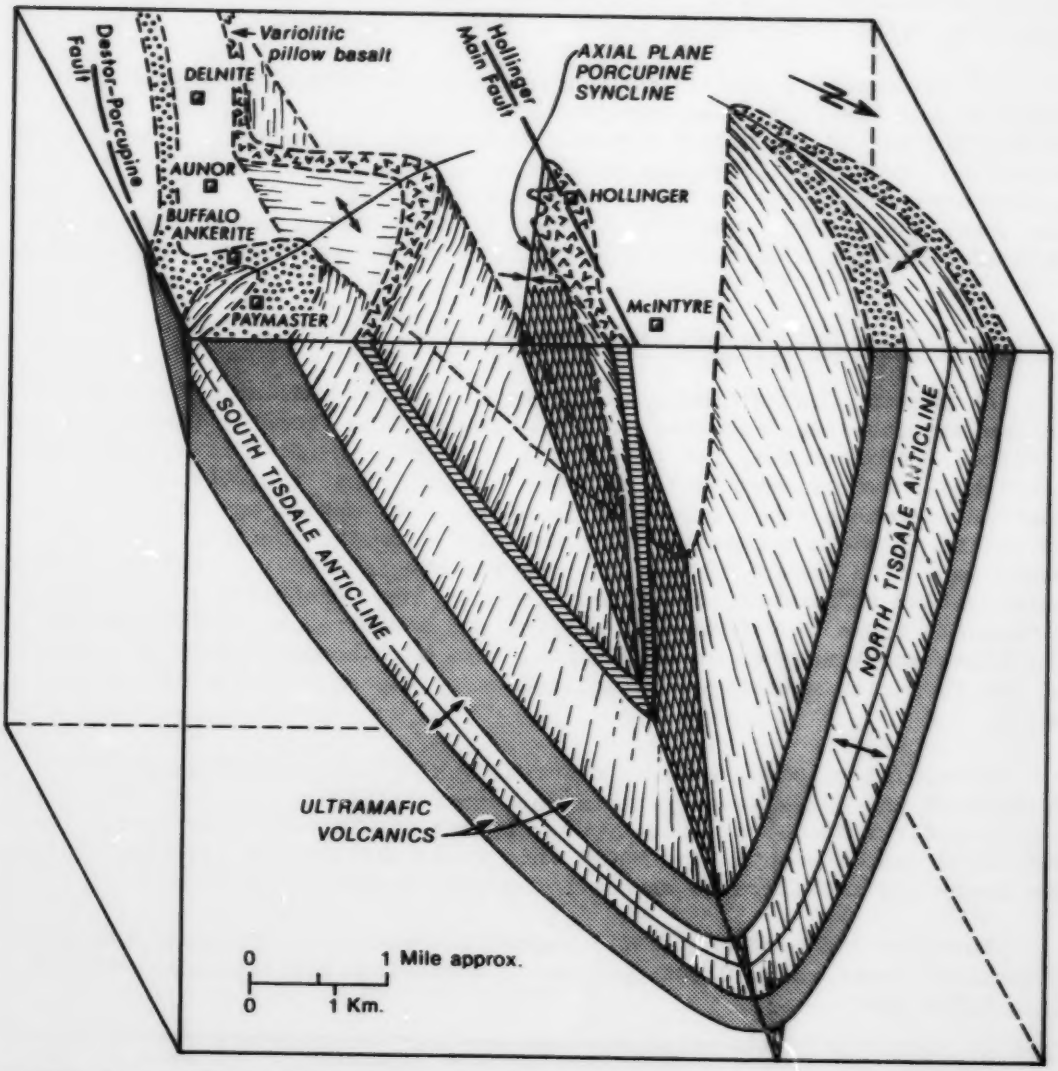


Figure 5. Diagrammatic sketch showing interpretation of main part of the Timmins gold camp; illustrates the refolding of an anticlinal structure (now represented by the south and north Tisdale anticlines) about the easterly trending Porcupine syncline. For line of cross-section see Figure 4.

are not polyphase folds, and in many cases the minor folds can be related to nearby faults rather than a regional fold pattern. In addition, the Krist formation which underlies the metasediments may also have been largely unaffected by the first phase of folding. Buffam (1948a) shows the underlying basaltic sequence to be folded and then subsequently truncated by the overlying Krist formation in southwest Tisdale Township.

In summary, the writer interprets the major fold pattern of Tisdale Township and immediately surrounding area as follows: Isoclinal folding of the ultramafic and mafic volcanic rocks about north-south axes; folding occurring largely prior to the deposition of the overlying felsic to intermediate volcaniclastic rocks (Krist formation) and clastic sedimentary rocks of the upper part of the Porcupine Group. Folding of the metavolcanics and metasediments about east-west axes giving rise to the Porcupine Syncline.

Analytical Data on Gold Content of Rocks

At present, background gold analyses[1] are not available for the rocks in the Timmins area, and therefore analytical data from the literature must suffice. Unfortunately the distribution of gold in rocks is not well established, however, available analyses indicate that the average gold content decreases from meteorites to ultramafic, mafic, and felsic rocks. In addition, there appears to be a decrease from the volcanic to plutonic equivalent of a rock. Shcherbakov and Perezhogin (1964) report the average gold content in five chondrites as 0.16 ppm, one achondrite as 0.01 ppm, ultramafic rocks as 0.0094 ppm, basalts and andesites as 0.0065 ppm and rhyolites and trachytes as 0.0054 ppm. The high concentration of gold in the iron-rich meteorites is indicative of the siderophile nature of gold.

According to Shcherbakov and Perezhogin (1964), Zavaritskii (1955) determined the correlation between gold content and iron, magnesium, copper and vanadium for a number of rock types. By far the highest correlation coefficient was between Au and MgO. This would reflect the affinity of gold for neso- and inosilicates as mentioned previously.

Turekian and Wedepohl (1961) report the average gold content of the ultramafic rocks to be 0.006 ppm, whereas basaltic and granitic rock contain 0.004 ppm.

Vincent and Crocket (1960) studied the distribution of gold in the Skaergaard intrusion and found that the gold content increased from the microdiabase and gabbro of the chilled zone to the olivine gabbro in the upper part of the section. The granophyre and other late differentiates contain much lower concentrations of gold.

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[1]Unforeseen analytical difficulties have temporarily delayed the completion of analyses previously scheduled to be incorporated in this paper.

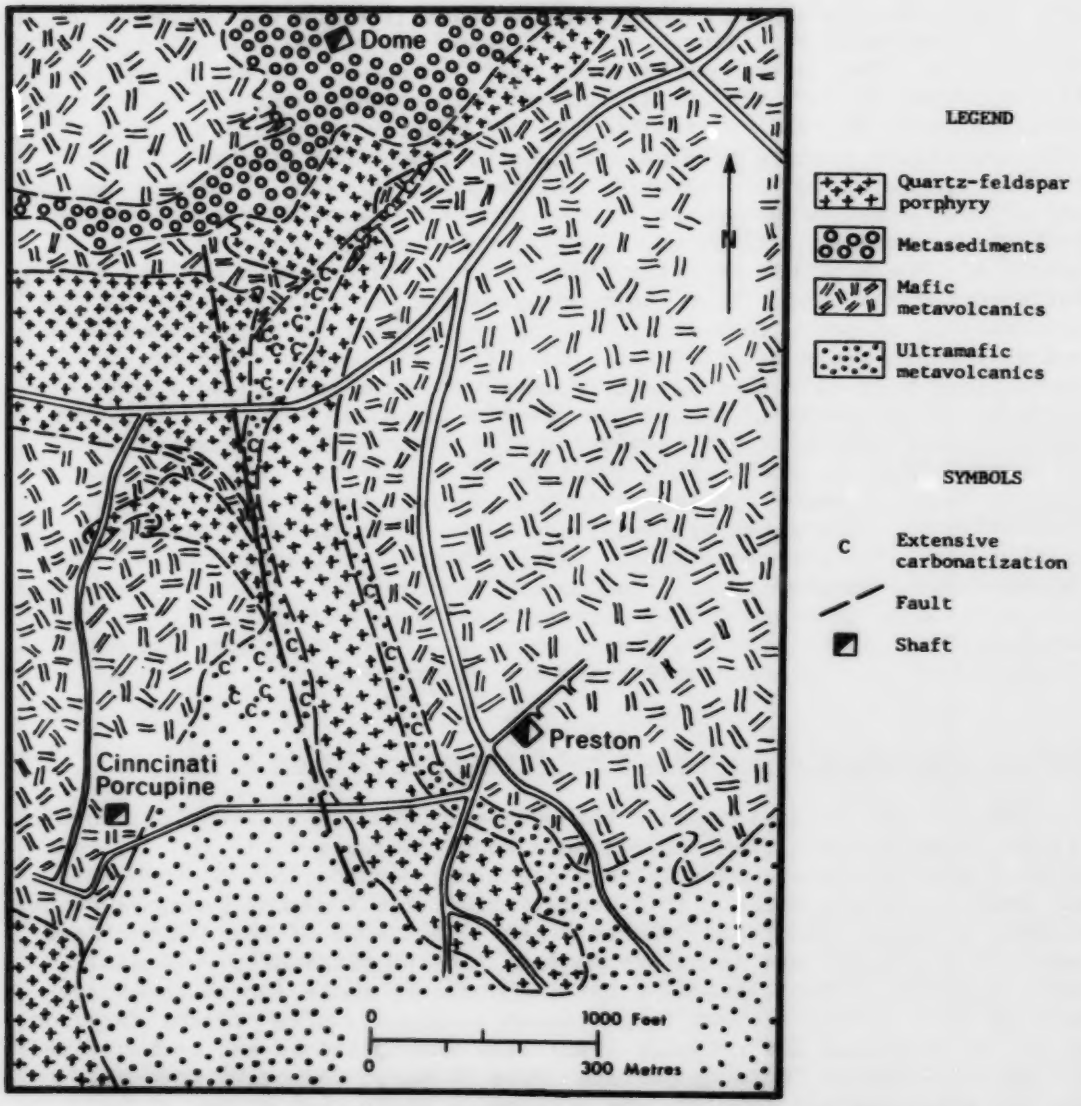

Figure 6. General geology of part of southeastern Tisdale Township illustrating proximity of ultramafic metavolcanics to various mines (Geology after Ferguson 1960)

Viljoen et al. (1969) present one of the more integrated summaries of the geochemistry of gold in relation to ultramafic and mafic rocks. In addition, Viljoen et al. analyzed 30 rocks from the Steynsdorp Goldfields for gold. They found the highest gold content (average 0.075 ppm) to be in a tuffaceous shale overlying komatiitic (high magnesium) basalts and ultramafic flows. They attribute the high gold content of the shales, which they consider to form the initial subeconomic concentration of gold in the area, to being derived by erosion from the underlying komatiitic rocks (the komatiites yielded gold values ranging from 0.005 ppm to 0.02 ppm). Further concentration of the gold into economic deposits is attributed to the dynamothermal metamorphism imposed by nearby granitic plutons on the tuffaceous shale as well as the underlying komatiitic volcanic rocks. Nearly all the economic deposits formed in the volcanic rocks close to the tuffaceous shale unit. From their analyses and other limited data on the geochemistry of gold, they concluded that the primitive high magnesium and ultramafic rocks of the Komatii formation may have carried two or three times more gold than younger normal-type basalts. In addition, analyses of carbonatized komatiitic basalts contained less gold than the non-carbonatized varieties, suggesting that during carbonatization gold is leached from the rock. This leaching of gold during carbonatization appears to be an important factor in the Timmins area, as commonly the ultramafic volcanic rocks spatially associated with the gold mineralization are largely carbonatized. Talc-carbonate, talc-chlorite and talc-carbonate-serpentine are also common associations. Moreover, abundant silica would be released during carbonatization of the ultramafic rocks, providing not only a possible transporting agent for the gold, but much of the quartz in the associated veins and stockworks.

Spatial Association of Gold Mines and Ultramafic Volcanic Rocks

Many of the gold mines near the southern boundary of Tisdale Township are in proximity to ultramafic volcanic rocks (Figures 4, 6, and 7), and in part some of the orebodies almost certainly occur within carbonatized ultramafic volcanic rocks. This would include the Preston, Dome, Paymaster, Buffalo Ankerite, Aunor and Delnite Mines. That some of the carbonatized rocks which contain ore zones are in fact altered ultramafic volcanic rocks is based on correlation of the carbonatized rocks (or in some cases talc-chlorite schists) shown in published sections (Buffam 1948b; Ferguson et al. 1968; Kinkel 1948; Taylor 1948) with known altered and carbonatized ultramafic volcanic rocks on surface (Pyke 1974a). Commonly, however, the ore zones are not found in the ultramafic rocks, but occur nearby in the more competent basalts, sedimentary rocks or porphyries.

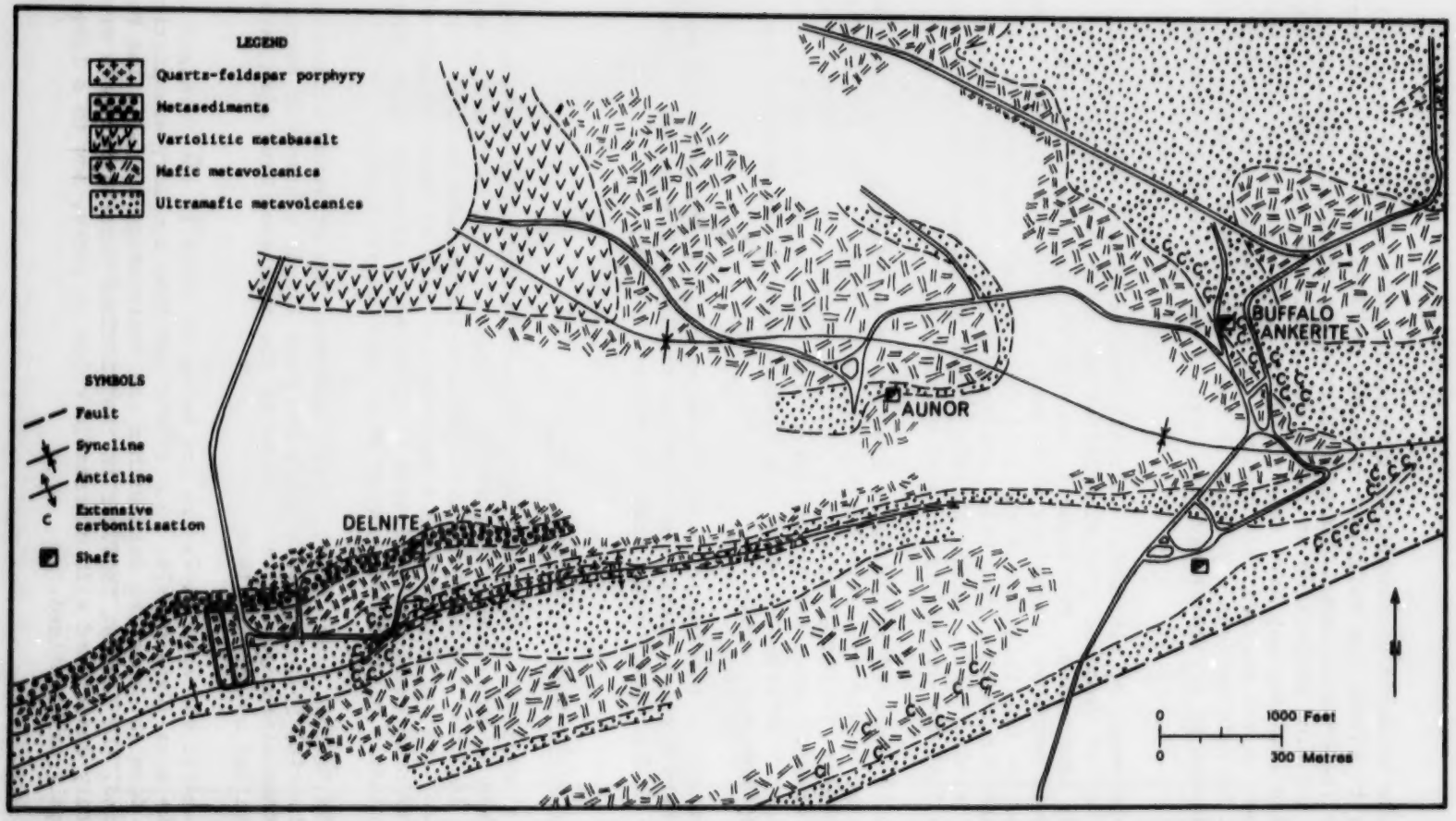

Figure 7. General geology of part of northern Deloro Township illustrating proximity of ultramafic metavolcanics to various mines (Geology after Ferguson 1958a,b).

To the writer's knowledge, no ultramafic volcanic rocks outcrop in proximity to either the Hollinger or McIntyre Mines two of the largest producers in the gold camp. However, ultramafic volcanic rocks could underlie the mine properties at depth, as illustrated in Figure 5; minor folding and faulting may have transposed the underlying ultramafic rocks much closer to the surface than depicted in the figure. Indeed, some of the chlorite-talc schists occurring in the lower levels of the McIntyre Mine (Ferguson et al. 1968) may form part of the ultramafic volcanic sequence.

The presence of ultramafic volcanic rocks does not, however, affirm the presence of economic gold mineralization; other factors appear to be of obvious importance. For example, many of the gold deposits are in proximity to porphyry intrusions which may, in part, have provided a heat source for the mobilization of the gold from the ultramafics. In addition, the intense deformation that the Tisdale Group rocks have undergone resulted in extensive fracturing thereby providing abundant dilatant zones to act as loci for deposition of vein material.

No gold mines of significance have been discovered in the Shaw Dome south of the Destor-Porcupine Fault, even though some of the ultramafic volcanic rocks at the periphery of the dome are close to or intruded by small granitic stocks. What may be lacking is the strong penetrative deformation and abundant fracturing to which the Tisdale Group rocks north of the fault have been subjected.

Elsewhere in the Timmins camp, other major gold producers can be shown to have a close spatial association to ultramafic volcanic rocks (e.g. the Hallnor and Pamour Mines in Whitney Township:

Comparison with Other Archean Gold Camps

Other important gold producing camps within Archean greenstone belts also contain an abundance of ultramafic volcanic rocks. Within the Abitibi Belt this includes the Holtyre, Kirkland Lake-Larder Lake and Val d'Or areas. Many smaller isolated gold deposits can also be demonstrated to be in an environment that was conducive to ultramafic volcanism (e.g. Porcupine Peninsula Mine, Munro-Croesur Mine, and Joburke Mine).

In the Holtyre area, Prest (1951) indicated the presence of numerous spinifex-bearing volcanic rocks which are most likely ultramafic volcanic rocks. Other ultramafic volcanic rocks in the same area have also recently been identified by Jensen (1974).

Ultramafic volcanic rocks are now known to occur in the Kirkland Lake-Larder Lake area (Jensen 1974; Pyke 1974b) and from acursory examination appear to form an extensive unit within the Timiskaming Series. The Kerr Addison Mine, the largest producer in the Kirkland Lake-Larder Lake area is intimately associated with ultramafic volcanic rocks, now to a large degree highly carbonatized.

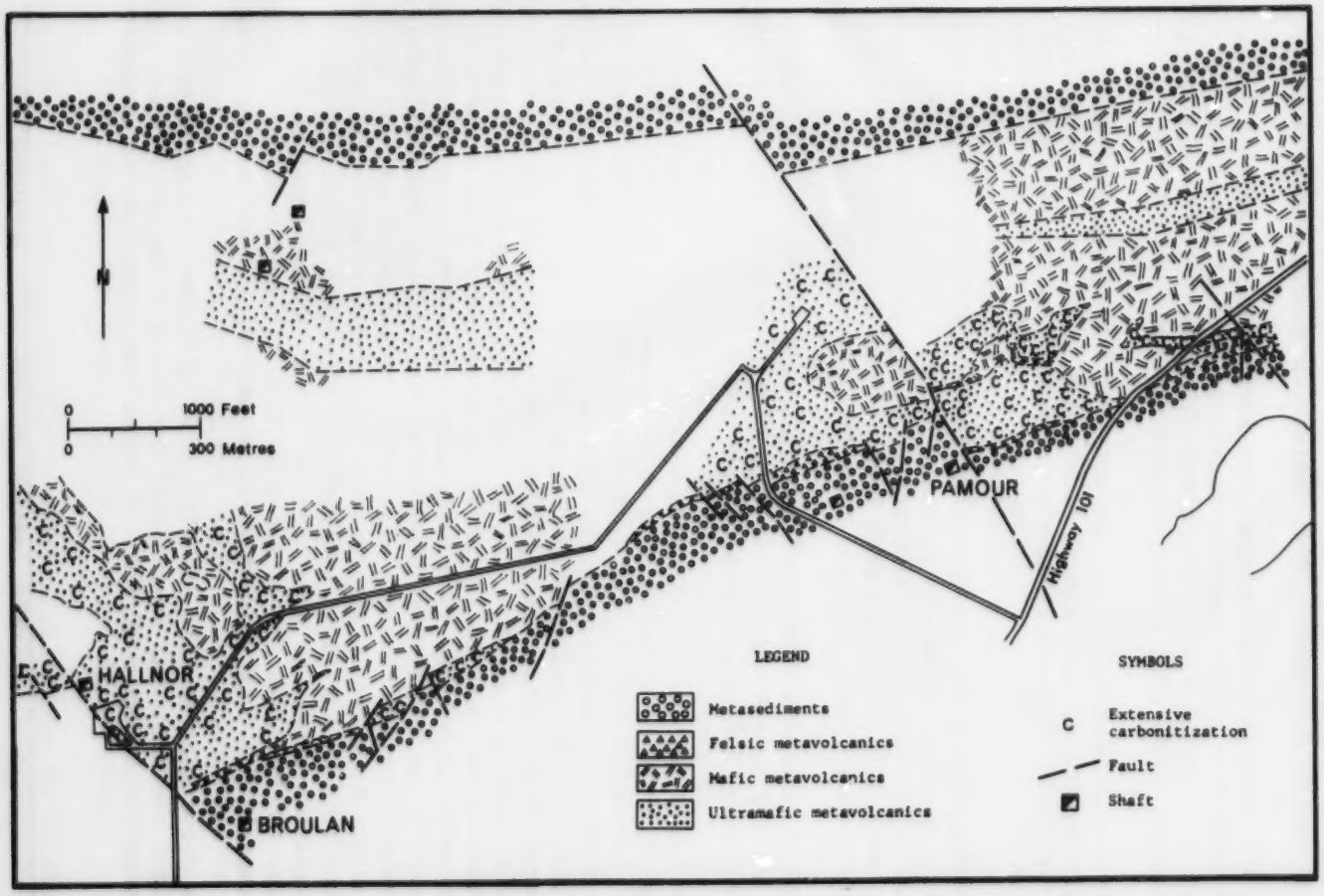

Figure 8. General geology of part of northern Whitney Township illustrating proximity of ultramafic metavolcanics to various mines (Geology after Ferguson 1958c,d).

Ultramafic rocks form an important part of the stratigraphic succession in the Val d'Or area (Quebec Ministere des Richesses Naturelles 1967). Many of these ultramafic rocks have recently been recognized as being of volcanic origin (U.K. and D. Kretschmar 1974, Cominco, personal communication).

It is probable that some of the ultramafic and carbonatized rocks in the Red Lake area of northwestern Ontario, that are associated with the gold deposits (Ferguson 1962; 1966; 1968; Chisholm 1951), are of volcanic origin (Ferguson 1975, ODM, personal communication).

As previously mentioned, Viljoen et al. (1969) recognized the possible genetic relationship between the ultramafic volcanic rocks of the Komatii formation and the gold deposits in the Barberton Mountainland area of South Africa.

In Western Australia, the Golden Mile of Kalgoorlie has recently been recognized to contain ultramafic volcanic rocks. Here, the Hannans Lake Serpentinite (Travis et al. 1971) which forms the basal formation of the Kalgoorlie succession, is considered to be of volcanic origin (G. Travis 1973, Western Mining Corporation Limited, Kalgoorlie, Australia, personal communication).

Perhaps the absence of ultramafic volcanic rocks may in some way assist in explaining why some Archean greenstone belts are lacking economic gold deposits, although numerous "showings" are known.

Conclusions

Many of the gold deposits in the Timmins area can be demonstrated to be in proximity to ultramafic metavolcanics (Figures 1, 4, 6, 7, and 8) and some ore zones to be within ultramafic metavolcanics. Available analytical data indicates that ultramafic volcanic rocks and probably associated high magnesium basalts (Viljoen et al. 1969) are anomalously high in gold as compared to other rock types. Analyses also suggest that carbonatization, of the ultramafic rocks may have lead to leaching of the contained gold, which was subsequently mobilized, along with the extracted silica, to be deposited in quartz veins in structurally favourable sites. This is strongly supported by the field association. Granitic intrusions and strong deformation appear to have provided (1) a dynamothermal mechanism necessary for the mobilization of the gold from ultramafic volcanic rocks and (2) necessary dilatant zones for the deposition of the auriferous veins.

If the above relationship is valid (i.e. that the ultramafic volcanic rocks provided the principal source bed[1] for the gold deposits) then the recognition and delineation of these volcanic rocks provides an extremely

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[1]Given that the concept of lateral secretion is valid, then many or all of the rock types probably contributed somewhat to the mineralized veins. In particular, it might be expected that the commonly associated komatiitic or high magnesium basalts may also have played an important, although a secondary role as a source of gold.

useful exploration tool, insofar as related gold deposits might be expected to have stratiform distributional elements. Prime exploration targets would include areas containing ultramafic volcanic rocks which display one or more of the following features:

(1) extensive carbonatization of the ultramafic rocks;

(2) ultramafic volcanic rocks intruded by or in proximity to granitic stocks;

(3) strong structural deformation.

Conceivably the recently recognized widespread and voluminous outpourings of ultramafic volcanic rocks during the Archean may have provided one of the major transporting agents of gold from the mantle during geological time. Dynamothermal metamorphism appears to have brought about remobilization of some of this gold to form economic deposits. Perhaps, as suggested by Viljoen et al. (1970), some or many of the detrital deposits of Proterozoic age were derived largely from pre-existing Archean deposits related to ultramafic volcanic rocks.

Undoubtedly the association of gold and ultramafic volcanic rocks is not applicable to all Archean gold deposits. Many other theories, notably that of Ridler (1970) which stresses the association of gold and exhalites, bear considerable merit. However, if sufficient deposits do have a genetic relationship with ultramafic volcanism, which may be the case, then recognition and delineation of ultramafic volcanic rocks could play an important role in the discovery of future gold deposits.

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